AN ATTEMPT TO SYNCHRONISE THE AUSTRALIAN, SOUTH AFRICAN, AND INDIAN COAL MEASURES.

PART I.—THE AUSTRALASIAN AND NEW ZEALAND FORMATIONS.

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PREFATORY NOTE.

The following attempt to obtain a general view of the Geological History of Australia and New Zealand between the close of the Devonian and the commencement of the Cretaceous periods, might not unfairly be called a "summary of summaries," or "comparison of comparisons;" since it accepts the outlines as drawn by competent authorities each for his particular district, places them side by side, and endeavours to unite them by transverse lines of isochronism. The same attempt has often been made with more or less success. But it is in the nature of things that our present conclusions on these matters can only be provisional, and will require modification and adjustment with every new advance in our knowledge.

The works to which I shall refer generally, and from which I shall quote without further notice, are the abstracts of the latest results of Geological work in the various colonies as follows, viz.:—In New South Wales, the Notes by C. S. Wilkinson, Government Geologist, in the annual reports of the Department of Mines; in Victoria, the Manual of Physical Geography and Geology by R. A. Murray, Geological Surveyor for the Department of Mines (Government Printing Office, Melbourne, 1887); in Queensland, the Handbook of Queensland Geology, by R. L. Jack, F.G.S., &c., Government Geological Surveyor; in Tasmania, a paper by R. M. Johnston, F.L.S., &c., in P.R.S.T., 1887; in New Zealand from the Outline of N.Z. Geology, by Sir J.

Hector, 1886. I have also used the Fossil Flora of the Coal, &c., by Tenison-Woods, in our Proceedings for 1883; Fossil Flora of E. Australia, &c., by Dr. O. Feistmantel, Proc. Roy. Soc. N. S. Wales, 1880, p. 103; Geology of Tasmania, by Johnston, Hobart, 1888; Invertebrate Fauna of the Hawkesbury, &c., by R. Etheridge, jun., Sydney 1888; Capt. F. W. Hutton on the Geology of New Zealand. Q.J.G.S., 1885, p. 191, &c., &c.*

I take this opportunity of expressing my extreme regret that in discussing Dr. Waagen's paper (Proc. Linn. Soc. ser. ii., Vol. III. p. 1802). I had omitted to refer to the sources from which it was mainly derived, Dr. Blanford's Montreal Address (B. A. Report for 1884, p. 691).

In the discussion of the true correlations between the Australian, South African, and Indian Coal Measures there seems—at least from my point of view—to be betrayed a kind of indefiniteness as to the lines upon which an enquiry which is as much Geographical as Geological should be prosecuted.

The problem set for solution has now been shown to be not so much purely palæontological as dependent on the reconstruction of ancient climates by the revelation of ancient Geographical conditions, such as position, extent and elevation of land surfaces, direction and strength of marine and atmospheric currents, and the alternations of glacial or interglacial periods caused by the varying eccentricities of the earth's orbit, in combination with that rotation of the axis which at long intervals bring the Northern and Southern Hemispheres each in its turn into Summer or Winter perihelion.

Regarding the *principles* of Dr. Croll's theory as sufficiently established, though unable to follow his developments of those principles with the same degree of acceptation, I cannot conceive

* I have purposely refrained from quoting from any author not easily accessible in this country, thinking that these Abstracts are sufficient for my purpose.

that we can properly correlate the phenomena of the Coal Measures of India and Australia, formations accumulated in opposite hemispheres, and different latitudes, by direct comparison.

The more reasonable course would be, I think, to investigate as fully as possible, the whole question in the Southern Hemisphere before entering upon its bearings upon the analogous question in the Northern.

But the opposite course has been pursued, owing probably to the far more perfect knowledge which has been gained of Indian Geology by the skilful, energetic and brilliant labours of the Geological staff of that country, than is as yet available for Australia. New Zealand, indeed, and Victoria have set an example which has been very timidly followed by the other colonies. Nevertheless, in spite of many difficulties and distractions the excellent geologists—too few, unfortunately, for the work—who are now engaged in these researches, have collected a great mass of information, out of which a connected history of this portion of the Southern Hemisphere may be provisionally constructed; and this paper is a humble essay in that direction.

To commence with New South Wales.

I think it may be convenient to give a brief summary of Mr. Wilkinson's report so far as concerns the period in question, even though it be familiar to all present, since inquirers away from Sydney often want and find it difficult to obtain this kind of information. Mr. Wilkinson here repeats that the Lower Carboniferous beds with *Lepidodendron*, *Calamites*, *Sigillaria*, &c., have been much disturbed, being tilted at all angles, and at the Copeland Goldfield, like the corresponding Maitai rocks of N.Z., traversed by auriferous quartz reefs, yielding from 1 to 15oz. per ton. Other beds are rich in marine carboniferous fossils. The Upper Carboniferous (unconformable) commence with marine strata of great thickness, implying long continued depression, which are very rich in characteristic fossils, succeeded by plant beds and coal seams (Greta, Anvil Creek, West Maitland), in which a flora which has been termed Mesozoic is abundant, displacing entirely the preceding types of vegetation. These coal measures are probably also represented at Hartley, Joadja Creek, Mt. Kembla, &c. Upon these rest the Upper Marine Beds, indicating another period of depression, and exhibiting a similar fauna with the Lower, with coarse and fine conglomerates containing striated boulders and yielding unmistakable evidence of Glacial action. (These are regarded by Mr. T. Oldham of the Indian Geological Survey as equivalents of the Talchirs.) Above these Upper Marine (Carboniferous) beds come the Middle Coal Measures, worked near East Maitland and at Rix's Creek, Singleton. Then about 2000 feet of strata without workable coal, and then again the Upper or Newcastle Coal Measures. These Middle and Upper Coal Measures contain *Glossopteris* (8 species), *Gangamopteris angustifolia*, *Phyllotheca Australis*, *Vertebraria Australis*, &c., with *Urosthenes Australis*. [*Urosthenes* is a genus of Ganoids which occurs also in the Carboniferous of Britain and North America, and not later. There seems therefore to be no good reason for separating the Newcastle beds from the rest of a series which is, up to its Upper Marine beds, undoubtedly Carboniferous in the British sense.]

It used to be assumed that the Hawkesbury formation immediately succeeded the Upper Coal Measures. Mr. Wilkinson, however, some years ago pointed out that on the right of the Shoalhaven, near Jordan's crossing, the Coal Measures had been eroded to a considerable extent before the deposition of the overlying rocks. I myself had long ago observed at Bulli, Mount Victoria, Hassan's Walls, &c., a series of red shales which appeared to intervene between the Hawkesburys and the Coal Measures, and had also noticed that a formation older than the Hawkesbury cropped out from under it upon the coast near Narrabeen. This I supposed to be the upper portion of the Coal Measures, and mentioned it as such to Mr. Wilkinson, who with Mr. David examined the ground, with the surprising result that these Narrabeen beds turned out to be a portion of the Clarence River series, yielding as they do, not *Glossopteris*, *Gangamopteris* and *Vertebraria*, but *Tæniopteris Daintreei*, *Alethopteris*

Australis, and *Thinnfeldia odontopteroides*, which are characteristic of that series. And at the same time these beds are found to correspond to the chocolate or red shales just mentioned. (These appear also about Coal Cliff and in the bores which have been put down between Sydney and Illawarra.) In a paper read April, 1885, before this Society, the Rev. J. Milne Curran maintained that the Clarence River beds are, on the fossil evidence, older than the Hawkesbury, and that the Ballimore beds near Dubbo are the first in succession above the Newcastle Coal Measures.

Mr. MacKenzie, the Examiner of Coalfields for New South Wales, has quite recently enlarged our knowledge of these most western coalfields by the discovery of *Glossopteris*, which is strong evidence for even a more remote date than that arrived at by Mr. Curran.

But a still more interesting fact has been ascertained by Mr. Wilkinson, as he has kindly informed me, in a recent official journey through the Clarence River district. He finds that the Narrabeen beds are at the base of the Clarence series, about 300 feet in thickness (on a rough estimate); that they contain coal seams which may be of some, at least, local value; and that they are succeeded by the Hawkesbury beds, which are again (in the Clarence River district) overlaid by the Upper Clarence beds, which also contain coal seams. This is an extremely important discovery, and clears up many difficulties.

I may, I hope, be pardoned if I here quote a few words from a paper on the Geology of the Clarence River district, read before this Society in December, 1883:—"The road from Grafton to Buccarumbi runs through a poor country of sandstones and shales, undulating in the valleys, but broken by ranges of mural precipices closely resembling the escarpments common in the Hawkesbury sandstone. The false bedding or oblique stratification so common in the latter series is equally predominant here, and the rock faces are excavated by atmospheric action into caves or 'gibber gunyas' of exactly the same character as those on the shores of Port Jackson or in the gullies of the Blue Mountains. The vegetation is also so similar that it is only by a kind of effort that one remembers that the formation is not the same." I think this passage is an amusing though rather humiliating illustration of the manner in which preconceived ideas may lead to the misinterpretation of obvious phenomena, even when they have been correctly observed.

The sequence of these formations appears to be as follows:—The Newcastle beds are succeeded by a blank in the record, indicating a period of unknown length, during which the Glossopteris flora was entirely swept away, not by any sudden cataclysm, we may be sure, but by the gradual alteration of climatic conditions. It may very probably have been a period of depression corresponding with an actual glacial period in higher southern latitudes, and contemporaneous with the formation of the Bacchus Marsh conglomerates, of which more hereafter.

To the same period the Estheria shales of 500 feet in thickness, proved by Mr. David, may perhaps belong. And the conglomerates of Lake Macquarie, Murrurundi, Wingelo, (?) &c., which rest upon the greatly denuded coal measures, may probably form the commencement of the new record.

The Clarence River series succeeds with its lower members, as at Narrabeen, overlaid somewhat irregularly by the great fluviatile deposits known as the Hawkesbury sandstone (Sydney sandstone of Dana and Jukes), which are thus intercalated in the Clarence River series, and contain *Thinnfeldia odontopteroides*, *Alethopteris Australis*, and *Odontopteris microphylla*, but no *Tæniopteris Daintreei*. Large numbers of Ganoid Fishes, and two or three species of Labyrinthodonts, *Mastodonsaurus* (?) and *Platyceps Wilkinsonii* (P.L.S. N.S.W., 1886) have recently been added to the known fauna of these beds, and, more remarkable still, *Tremanotus Maideni*, a Bellerophontid mollusc, with siphonal openings along the keel, has been described by Mr. Etheridge from Cockatoo Island, where it was found in association with the thoracic plate of *Mastodonsaurus* (?) determined by myself.* It is an extraordinary instance of survival, but is here especially interesting as proving the estuarine character of at least this stage of the Hawkesbury formation in the Sydney area; a view which I confess seemed to me so inconceivable, in the previous entire absence of marine remains, that I readily accepted this fossil, without examination, as a freshwater mollusc. It is important to remember with regard to these Hawkesbury Sandstones, that they also, at least in the upper portion, offer sufficient evidence of Glacial action, as has been particularly shewn by Mr. Wilkinson, and by Mr. David in a paper on Glacial action in Australia read before the Geological Society, Q.J.G.S., May, 1887, although it does not seem to have met with a very cordial reception. †

I quote again from Mr. Wilkinson: "The surface of the Hawkesbury Formation was denuded and worn into hollows before the Wianamatta beds were deposited." (See also Clarke, Sedimentary Formations, &c., p. 72), "and the latter in their lithological characters show that great physical changes must have taken place, for they consist chiefly of argillaceous shales, which are in striking contrast with the thick bedded arenaceous rocks underlying them. The fine sediment which formed the Wianamatta shales evidently settled down in the quiet waters of a lake." *Thinnfeldia odontopteroides, Alethopteris Currani, Odontopteris microphylla* and *Phyllotheca Australis* continue from the Hawkesbury, but *Macrotæniopteris Wianamattæ* and *Gleichenia* sp., appear as new species. The genus *Palæoniscus* is common to both, and both yield

*This genus, on account of the siphonal openings, has led to the removal of the family from the Heteropoda to "a position near the Fissurellidæ and Haliotidæ, and between these groups and the Pleurotomariidæ."

†In the discussion of this paper Professor Boyd Dawkins is reported to have said that "he had found *Glossopteris* to the west along with Lepidodendroid plants of Mount Victoria." I suppose we should read "*Glossopteris* along with Lepidodendroid plants to the west of Mount Victoria." There is plenty of *Glossopteris*, but if any Lepidodendroid fossil was found there it must have been a lower carboniferous or upper devonian form, possibly from Mount Lambie, or perhaps as a transported and foreign fossil from the upper marine (glacial) beds.

Labyrinthodont remains, but from the Wianamatta Mr. Etheridge (in his report mentioned above) also describes two species of *Unio* and two species of *Unionella*.

It seems a plausible hypothesis that the Upper Clarence Beds may have been more or less contemporary with the Wianamatta Shales. But, in any case, above these Wianamatta or Upper Clarence beds we have no later formation, marine or fresh-water, on the eastern side of the colony,—but on the right bank of the Darling we find the Cretaceous marine beds which are so largely developed in Queensland, and which probably come near the marine beds of Uitenhage in South Africa.

The whole series—as determined from the work of the Rev. W. B. Clarke, Mr. Wilkinson, Mr. David, Mr. Etheridge and the Rev. J. M. Curran, is as follows:—

	Formations.	Climate (Supposed).
	Paroo beds, Marine, Cretaceous	(?)
	Break in the Record (?).	
1 (?)	Wianamatta Shales, lacustrine, 700 ft. Clarence River Upper Coal-Measures, 500 ft. (?)	equable.
2.	Hawkesbury Sandstone, fluviatile, 1000 ft.	extreme.
3 (?)	Clarence River Lower Coal-Measures, 300 ft. (?). Narrabeen beds	equable.
4.	Lake Macquarie Conglomerate Estheria Shales, Flooded Plains (?), 640 ft.	extreme.
5.	*Break in the Record.*	
6 (?)	Ballimore Coal-Measures Upper or Newcastle Coal-Measures	equable.
7.	Barren Shales, Floods and Droughts (?), 2000 ft.	extreme.
8.	Middle Coal-Measures	equable.
9.	Upper Marine beds	extreme.
10.	Lower Coal-Measures	equable.
11.	Lower Marine beds	extreme.
12.	*Break in the Record* (?).	
13.	Lepidodendron beds	equable.

QUEENSLAND.

From Mr. Jack's Handbook of the Geology of Queensland, which contains also much of Mr. Daintree's observations, we obtain the following ascertained facts:—

The Lower Carboniferous with its characteristic fossils appears at Gympie. In the Star basin also, at the junction of the Big and Little Star Rivers, tributaries of the Upper Burdekin, we find besides Marine Carboniferous fossils, *Lepidodendron australe*, *Knorria imbricata*, &c., these beds being no doubt identical with the *Lepidodendron* beds of Gloucester, Goonoo Goonoo, &c., N.S.W. The same beds with a similar but better preserved flora occur also in the Drummond Range, which forms the watershed between the Belyando and Mackenzie Rivers, and is intersected by the Central Railway.

Here the Carboniferous Flora ceases, as elsewhere, abruptly, and we find the *Glossopteris* beds of our *Upper Carboniferous* appearing in the Bowen River Coal Field, in which three distinct series of sedimentary rocks are presented. At the base of this formation we find white and red sandstones overlaid by the bedded trappean rocks of Mount Toussaint, Mount Divlin and Mount Macedon. They are succeeded by Series II., chiefly marine, with strong evidence of Glacial action, and *Glossopteris*, and are identified by Mr. Jack with our Lower Coal, and Lower and Upper Marine beds. The Third Series, of freshwater formation, which is represented also at the Oakey Creek (Cooktown), Little River (Palmerville), and the Dawson-Comet-Mackenzie Coalfields, with *Glossopteris Browniana*, *Phyllotheca Australis*, &c., corresponds to our Upper Coal Measures.

In the Burrum Coalfield, extending from the Burnett River to Maryborough, and near Rockhampton, *Glossopteris Browniana*, and *Tæniopteris Daintreei* occur in association, a fact which has been thought to be repeated in the Jerusalem Coalfield of Tasmania; and Mr. Jack observes that "it seems probable we have here a series of passage beds bridging the gap between the Bowen and Ipswich Coalfields." This gap, in which *Glossopteris* is about leaving the stage and *Tæniopteris* has already appeared, must, one would suppose, correspond in position more or less to the hiatus to which I have already referred between the Newcastle and the Clarence River series.

The Ipswich or Brisbane River coal measures correspond without doubt to the latter (Narrabeen and Clarence River), containing as they do *Tæniopteris Daintreei*, *Cyclopteris cuneata*, *Thinnfeldia odontopteroides*, *Alethopteris Australis*, &c.

But in Queensland this formation *seems* to be continuous with the Cretaceo-jurassic, which we have already met with on the right bank of the Darling, but which is of vast extent a little further north.

There appears to be no break in the continuity of the Ipswich beds with the great Rolling Downs formation, "which contains a marine fauna (and occasionally freshwater) representing the migration of many species which in Europe date from Rhætic to Cretaceous, but which cannot be quoted as arguing a strict contemporaneity of life." (Jack, l.c. p. 67.)

It is not difficult to understand the survival of Triassic forms in these regions, since many such remain to this day. But it is very difficult to imagine that a large number of fossils of Cretaceous character should have appeared in the southern hemisphere so far in advance of the northern as to alter the character of a true Jurassic fauna.

The mode in which these fossils chiefly occur, in nodules lying upon the general surface of the ground, seems to suggest that a considerable erosion of the softer portion of the deposits, has carried away all the mass which once overlaid the present surface, and has left behind it the hard and heavy concretions which had formed around the organic remains of many periods in succession, so that Cretaceous fossils from the highest and first denuded beds are mingled with Jurassic forms from the lower and last denuded. Otherwise we must inevitably be drawn to the conclusion that the *Tæniopteris* flora extended its duration into a period contemporaneous with (at least) the Lower Cretaceous in the Northern Hemisphere. This would bring the Hawkesbury beds with their

Labyrinthodonts, *Tremanotus*, &c., to a period near that of the Upper Jurassic; a position not apparently quite consistent with the fauna; yet it is not an inconceivable solution of the problem.

The succession, as recorded in Queensland, is therefore

Rolling Downs, Marine Lower Cretaceous. = Paroo beds, N. S. W.

1-4.	Upper, Ipswich, &c., Coal-Measures	Upper Clarence R. Hawkesbury, Lower Clarence.
5.	Burrum Coal-Measures.	*Break in the record.*
6-11.	Bowen Coal-Measures, 3rd series	Upper and Middle C.M.
	Bowen Marine, glacial, 2nd series	Upper Marine beds
	Bowen Sandstones, 1st series	Lower C.M., Lower Marine.
12.	*Break in the record.*	
13.	Drummond Range beds, &c. (Lepidodendron flora)...	Stroud beds, &c.

The correspondence with the formations of New South Wales is, as might be expected, clear enough in general outline; and it may be confidently expected that between the two series a fairly complete history of the East Australian Lands during the Carboniferous and Mesozoic periods may be ultimately constructed.

Victoria.

The Geology of this Colony has been pretty well worked out in many especially the mining districts; but the Mesozoic beds have received less systematic investigation;—and it is with these that we are here principally concerned. For, with the exception of certain *Lepidodendron* beds upon the river Avon in Gippsland, there is no Carboniferous record whatever in the country; and these ought very likely to be ranked as Devonian. Nor is there even any *Glossopteris* to be quoted, whether Carboniferous or Mesozoic; but the next beds the Avon sandstones—after a very long interval — are the *Gangamopteris* beds of Bacchus Marsh, which are said to afford unequivocal evidence of Glacial action, and are at the same time probably related in some way or other to the Newcastle Coal Measures which contain both *Gangamopteris* and *Glossopteris.*

These *Gangamopteris* sandstones and glacial conglomerates of Bacchus Marsh, resting partly on strongly folded and denuded Silurians and partly on the older volcanic rocks, have generally been regarded as the equivalents of the Indian Talchirs, which, as stated above, are supposed to be represented by the Ecca glacial conglomerates and *Glossopteris* shales in South Africa; and by the Upper Marine Beds in New South Wales. But Feistmantel with more reason—as it seems to me—places the Bacchus Marsh beds *above* the Upper Coal of N.S.W. (Proc. Roy. Soc. N.S.W., Vol. XIV. 1880, p. 111).

Above these *Gangamopteris* beds of Victoria succeed the Carbonaceous (so called) beds, the last, if not the first, of the Victorian Mesozoic, with two species of *Unio*, three of Cycads, and, more important for our purpose, *Pecopteris* (*Alethopteris*) *Australis*, and *Tæniopteris Daintreei.*

Now these same ferns of the Carbonaceous rocks of Victoria occur also together in the Clarence River beds, so that there can be little doubt of the correctness of their identification, which, indeed, has not to my knowledge been questioned. But the discovery of the Narrabeen beds, and their identification with the lower beds of the Clarence River, involving the claim of the latter to a position intermediate between the uppermost *Glossopteris* beds (*i.e.*, the Newcastle Coal Measures), and the Hawkesbury sandstone alters the argument in some respects. Granting, as we must, the correspondence of the Carbonaceous beds with the Clarence River series, including the Hawkesbury sandstones, we must look for a quite different horizon for the Bacchus Marsh Glacial beds than that mentioned above. The absence of *Glossopteris* in the one case, as compared with its luxuriance and variety in the other, has always presented some difficulty in the way of accepting the identification of the Bacchus Marsh and Upper Marine Glacial and Boulder beds. It seems to me that the evidence is in favour of Feistmantel's correlation of the Lower Bacchus Marsh beds with the blank space above the Newcastle series, in which case the overlying *Tæniopteris* beds come out directly in their accepted position, equivalents of the Clarence River and Hawkesbury deposits.*

The Victorian series is, therefore, apparently to be rearranged as follows, by an adaptation of the list given in Murray's Geology of Victoria, p. 85.

1, 2, 3.—Carbonaceous rocks of the Wannon, Cape Otway, Western Port, and North Gippsland—Coal Measures and sandstones—corresponding to the Clarence River series with the intercalated Hawkesbury sandstones, which are probably represented by similar fluviatile formations in Victoria, especially in the Cape Otway district.

5.—Bacchus Marsh conglomerates and sandstones with evidence of Glacial action, and with *Gangamopteris*, corresponding to some part of the great blank in the New South Wales record, between the Newcastle Coal Measures and the Lake Macquarie conglomerate.

6-12.—No record of any part of the period which elapsed between the close of the Lepidodendron era in New South Wales (Stroud, &c.,), and the uppermost Newcastle beds; that is to say, of the whole *Glossopteris* period, together with the undefined age of change which immediately preceded it.

13.—Lepidodendron beds on the Avon, Gippsland, corresponding to those of New South Wales.

I should wish to draw particular attention to the Glacial character of the Bacchus Marsh conglomerates, as indicating that

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* This was practically Feistmantel's conclusion before the Clarence River beds were removed to their true position, before the discovery of Labyrinthodonts in the Hawkesbury sandstones, and, of course, before Mr. Wilkinson's discovery of the intercalation of the latter formation between the lower and upper members of the Clarence River beds.

the blank period in which the disappearance of the *Glossopteris* flora took place was one of extreme or severe climatic conditions, accompanied by development of Glacial phenomena either generally or under local conditions.

Tasmania.

In Tasmania we find no Lepidodendron beds, nor any other record of upper Devonian or lower Carboniferous. The marine beds of Eastern Tasmania, with *Productus brachythærus*, &c., and evidence of Glacial action (Bruni Island and elsewhere), are classed by Mr. Johnston as equivalents of our Lower Marine series, with which they sufficiently correspond. But the Mersey (or Lower) Coal Measures, with *Glossopteris* (?), *Gangamopteris* and *Noeggerathiopsis spathulata*, etc., seem to correspond rather with our Middle and Upper Coal Measures, than with the Lower or Greta Coal, with which our author correlates them. If so, these Tasmanian "Lower Marine" beds may represent the whole of our Lower Coal Measures and "Marine" beds; and the Mersey Coal Measures, our "Middle and Upper Coal Measures." But the Tasmanian "Upper Coal Measures" are plainly the same as the Clarence River and Ipswich beds, in all of which *Glossopteris*, previously so abundant, disappears for ever. A doubtful case of *G. linearis* and *G. moribunda* is indeed reported from some of these Upper Coal Measures in Tasmania, just as Mr. Jack mentions another species still surviving in the Burrum basin. But otherwise the fossil flora clearly indicates this identification, which extends even as far as South Africa, where the Stormberg beds contain the very same species, as successors to the same species (?) of *Glossopteris*.*

* Since writing the above I have received a note from my brother, Mr. Stephens, M.A., F.G.S., of Hobart, mentioning that a fossil heterocercal Ganoid, probably a species of *Palæoniscus* though in imperfect preservation, has just been discovered in the Knocklofty Sandstone, belonging to the highest formation of the Upper Palæozoic marine beds in the south of the island. The identification of this fossil will be looked for with some interest. Its occurrence, however, is some evidence in favour of a fluviatile origin for this sandstone, which may possibly, like the Hawkesbury beds, be ultimately relegated to a later period than was originally thought probable.

New Zealand.

In New Zealand the Lower Carboniferous beds have as yet yielded no plant remains. They consist in the lower beds of limestones with characteristic marine fossils, gradually passing upwards into unfossiliferous fine grained argillaceous slates. (Hector, Outline, &c., p 78.) We are not warranted, it seems to me, in assuming that the Lepidodendroid Flora of the Lower Carboniferous in Australia and Africa ever had existence in New Zealand, although there must have been land surfaces, with some kind of flora.

That those islands were more or less directly connected with Asia and Australia during some part of the Mesozoic period is extremely probable, if not absolutely certain. But there is nothing to indicate any earlier connection on this side, and we are quite certain that there was none in the subsequent ages; though it is probable enough that at more epochs than one New Zealand may have formed an outlying portion of an Antarctic continent.

However this may be, the next in sequence, the Oreti-Kaihiku series, regarded as Permian on the ground of its Molluscan fauna (though containing also Saurian remains (*Ichthyosaurus*) and Labyrinthodont (?) teeth, and remarkable for the "absence of *Spirifera*, *Productus*, and the other usual Palæozoic elements of a Permian fauna," both of which facts appear to indicate a Mesozoic rather than a Palæozoic position, (Hector, lib. cit.), presents, in its lower portion, a glacial conglomerate or boulder formation "resembling the character described for the base of the Gondwana series in India," and above this one species at least of *Glossopteris*. It is impossible to recognise in the marine fauna here quoted (Permian Molluscs and *Ichthyosaurus*) or in the (probably) Labyrinthodont remains, any resemblance to our Upper Marine (Carboniferous) beds, however much they may appear to correspond in their evidence of glacial action.

But let us consider the series which follows. The Wairoa-Otapiri series, with a fauna of very mixed character, combining some surviving Permian forms with a great majority of distinctly Triassic character, and a few which are Jurassic in Europe, has been on the whole regarded as Triassic, the Wairoa beds even as lower Trias. Yet the presence of *Belemnites otapiriensis,* which is near *B. elongatus* of the English Lias, along with *Pleurotomaria ornata* and *Tancredia truncata*, which are "Oolite forms," (Hector l.c. p. 71), must not be neglected. In this formation there are also fresh water beds, with *Glossopteris*, *Zamites*, and *Rhacophyllum.* Now, looked at from the northern standpoint, all our Mesozoic and post-Mesozoic formations appear of a mixed character, like what are called Passage beds in an area of definite formations. And in the same manner the corresponding formations in the northern hemisphere would present to the Antarctic geologist, who had commenced with our Australasian and South African fossils and had studied these alone, a similar confusion and mixture of heterochronous characters. Yet in view of the much more rapid and extensive dispersal of animals, and especially of marine animals, than of plants, and the great preponderance of the Holarctic region in abundance and variety of forms, both vegetable and animal, in view also of the evidence of a general drift of these forms to the southward, at least since the commencement of Mesozoic times, and taking into account the generally feeble character of the return current or remigration towards the Equator, by which some types are creeping north from the now sunken Antarctic continent and its still extant outliers in New Zealand, Tasmania, and Eastern Australia, South Africa and South America, we may come to a general conclusion that a large number of contemporary northern types found fossil in any southern marine formation indicates a nearly synchronous but later period for the southern than for the northern equivalent; so that a Southern Cretaceo-jurassic Fauna should be considered as synchronous with, or even a little younger than the European Cretaceous, and a Liasso-triassic assemblage, on the same principle, as Liassic; except where there is reason to suppose that the Liassic element is of Southern origin, in which case we should accept the Triassic position.

I should therefore regard the Oreti-Kaihiku as, at any rate, not more ancient than Triassic, and as properly correlated with the Clarence River and Hawkesbury beds, with their Labyrinthodont fossils; and in the same way I should suppose the Wairoa-Otapiri series to extend upwards into the Oolitic period of the northern hemisphere. (See Capt. Hutton, Geol. N.Z., Q.J.G.S., 1885.)

It is true that in both of these series we find the record of *Glossopteris*, a fact which seems to militate against the view here proposed, since in New South Wales this form is undoubtedly Palæozoic, and perhaps truly Carboniferous. But it appears to me that *Glossopteris* must have continued to exist in New Zealand long after its complete disappearance from New South Wales, the region in which it had been present earlier, in greater abundance, and with more numerous species than in any other known part of the Southern Hemisphere. And therefore, disregarding *Glossopteris*, and relying on the presence of Saurian and Amphibian remains, and the absence of *Spirifera* and *Productus*, I cannot but think that the Oreti-Kaihiku comes in above our upper coal, and that the glacial period which the base of this formation records in New Zealand, was the same period which, without leaving any tokens of its presence, and very possibly without any accumulation of ice at all, closed our Upper Carboniferous period by putting an end to the flora characterized by *Glossopteris*, *Vertebraria*, &c. If so, the Clarence River and Hawkesbury formations may together form the equivalent of the combined Oreti-Kaihiku and Wairoa-Otapiri.

The succeeding formations in New Zealand are classed by Sir James Hector as Liassic, Jurassic and Lower Greensand, and represent the Rolling Downs formation and the Uitenhage of S. Africa. Capt. Hutton, however, regards them as *Lower* Jurassic (l.c. p. 194). Omitting them therefore from our present consideration we shall have a conjectural list of parallel formations made out as follows :—*

	NEW ZEALAND.	NEW SOUTH WALES.
1.	Mataura series, No. VIII., Hector, l.c. "Jurassic" ...	Wianamatta.
	Macrotæniopteris lata ...	*M. Wianamattæ.*
	Tæniopteris Daintreei, Clent Hills, N.Z.	
	Otapiri-Wairoa (No. X.), "Triassic"	Upper Clarence beds.
	Glossopteris, Labyrinthodonts	
2,	Oreti conglomerate—evidence of ice	Hawkesbury beds, Labyrinthodonts.
3.	Kaihiku beds (No. XI.), "Permian"	Lower Clarence beds, Narrabeen, &c.
	Glossopteris, Labyrinthodonts.	
4.	(?)	Conglomerates of Lake Macquarie, &c.
5.	*Break in the record.*	
6-11.	Maitai series, No. XII., "Carboniferous"	Glossopteris beds, Newcastle C.M. to Lower Marine.
	Spirifer bisulcatus, *S. glaber*, *Productus brachythærus*, *Cyathophyllum*, *Cyathocrinus.*	
12.	*Break in the record.*	
13.	Te Anau beds (No. XIII.), "Devonian" (?)	Lepidodendron beds at Stroud, &c.

If we endeavour to reconstruct for ourselves the varying aspects of the whole region during the vast extent of time over which we have glanced, we shall see some such succession of Physiographical features as the following :—

* See Proc. Roy. Soc. N.S.W. Vol. XIII. 1879, p. 68, for a provisional classification by Sir James Hector, which however, as was inevitable at that time, contains many misapprehensions as to the succession on our side.

First,—we behold an Australian group of islands extending from below the Tropic, and perhaps even from the Asiatic continent, up to an Antarctic Archipelago or continent, which is also approached in like manner by two other oceanic lands; one, a group of islands to the east, representing the present New Zealand, the other, a great way further to the westward, being the southern prolongation of the African continent; but we cannot make out anything of the corresponding extremity of South America.

In all of these are ranges of mountains rising into the clouds above those areas which are marked in geological maps as occupied by the older crystalline rocks, their summits white in many regions with perennial snows, and fostering glaciers in their upper hollows. The lower hills, where they are shaped out of sedimentary rocks, are full of the fossils which we call Silurian or perhaps also Devonian. If we confine our attention to the Eastern portion of the area roughly marked out above, that is to say, Eastern Australia, New Zealand, and the intervening portion of the Pacific, disregarding the larger western part formed by Western Australia, the Indian Ocean and South Africa, but remembering at the same time that both the seas mentioned are practically landlocked towards the south, we shall see that the warm equatorial currents of the Pacific which then as now flowed southwards along the eastern shores of both the eastern and the western islands, and through the various channels which divided each of those groups were not as now confronted, split up and chilled, in or about "the forties," by a vast and continuous flood of cold water from the west, nor by the influx of still colder drifts of iceladen currents from the polar seas, but were defended from both by tracts of land which at the present moment are submerged. The currents flowing from the equatorial regions were thus forced to return along the northern shores of the Antarctic lands, warming them as the Gulf Stream now warms the coast of Norway, and to complete their circle by bathing the western shores also of New Zealand, which thus lay between two currents, one much the warmer, running southwards, the other cooled but not chilled, flowing to the north. (Somewhat similar to this was the system of circulation in the Western or Indian Ocean, though on a much larger scale.)

Hence the climates were warm and moist, the land surfaces below the snow line were clothed with luxuriant vegetation, and the sea swarmed with animal life of familiar Carboniferous types. The maritime lowlands, especially in the eastern portion of the Australian group, were covered with forests or jungles of Lepidodendra, Calamites, and the other allied forms with which we are so familiar in the Carboniferous formations of the Northern Hemisphere. In the more northerly parts of the same group such forms were abundant on both eastern and western flanks of the principal islands; but towards the south they became more and more restricted to the moister and warmer east. As the land rose towards the mountains the vegetation grew less luxuriant, and began to consist principally or at least most conspicuously of ferns and Equisetaceous plants of humbler growth and hardier habit; until at the higher level the plants became for the most part reduced to ferns of creeping or scrambling habit, with simple fronds not unlike some of the existing Polypodiums, accumulating in thick matted brakes, the lower beds of which were gradually being consolidated into peat.

Among these, especially near brooks or in swamps, were dense reed-beds of Horsetails or similar plants. In short, the flora of these high lands was of what I have already named the Glossopteris type; while the dense and rank vegetation of the shores was the Lepidodendron flora of the Northern Hemisphere, of the Drummond Range, of Tamworth, Stroud, Cobar, Gippsland, Grahamstown in S. Africa, and other places known and unknown. It did not however extend, so far as I can see at this distance, into the latitudes of Tasmania, nor into the New Zealand group to the eastward. This is the first picture in the geological magic lantern, the first of the epochs under our consideration.

After a long interval of darkness in which we can discern nothing clearly, but have an indistinct perception of great variations in level, vast volcanic disturbances, and consequent geographical alterations, we again begin to see in a glimmering light the landscape as before, but in a strangely altered state. Subsidence of the land or rising of the sea has opened ways for the cold ocean currents from the west, and the still colder water from the icy south. The maritime regions that formerly bore the exuberant jungles of the Lepidodendron flora are now below the sea-level. The climate in general is severe and stormy, modified of course by local conditions. The snow line has descended, and before it the Glossopteris flora has been gradually forced likewise, step by step, to a refuge in the low lands.

Strange as it may seem, it is nevertheless certain that however extreme the transformation of the landscape may have been, the waters of the sea and their inhabitants underwent no sufficient hardship to alter their character. From the last preceding marine fossiliferous beds we find the following genera and species still surviving, viz.: *Cyathophyllum*, *Amplexus*, *Syringopora*, *Favosites*, *Strophalosia*, *Chonetes*, *Orthis*, *Rhynchonella pleurodon*, *Atrypa*, *Spirifer*, *Tellinomya*, *Aviculopecten*, *Pterinea*, *Dentalium*, *Murchisonia verneuiliana*, *Pleurotomaria*, *Euomphalus*, *Loxonema*, *Goniatites*, *Orthoceras* (Report Dep. Mines, pp. 57-67). I have no doubt that this list will be largely increased by further identifications in the older or Devonian beds.

This is our third epoch—that of the Lower Marine beds. In the fourth—the Lower Coal Measures—we see the land again emerging, broad valleys opening upon well-watered plains; a climate, if not warm, at least constantly temperate, moist, and eminently favourable to the growth of the Glossopteris flora, which is now occupying wide areas with the peat mosses which are to be the "Lower Coal" of the future. On the drier elevations we see forests of Araucarias and other conifers. But the snow line is still at a lower level than in the Lepidodendron time, and the glaciers, in consequence of the abundant precipitation of aqueous vapour, descend even lower than in the colder period immediately preceding. Except in the more northern parts, as before, the western shores of the Australian islands have a drier and colder climate, and a much less abundant growth of the eastern flora. We cannot see what the vegetation of New Zealand is, but conjecture it to be scanty, developed as it must have been from very small remnants of a scanty indigenous flora. Few forms could have survived the severities which had destroyed the Australian Lepidodendra. (For even here in Australia the destruction of species must have been enormous, and the number of survivors very few, as the vast profusion of individuals and fewness of species which is so marked a feature in our Upper and Middle Coal Measures clearly shows. Yet here was a large quasi-continental area, extending far towards the north, on which to draw for replenishment of the recovered land, while New Zealand does not seem *at that time* to have had any advantage of the sort.) The emergence of the land has again barred the channels of the old currents from the west and south, and the genial, or at least equable, climate of the former period has been renewed. Why, then, has not the former vegetation recovered its place? The same plants as flourished here in the reign of the Lepidodendron flora of Australia are flourishing still in jungles as thick and luxuriant as before, in Brazil, and in vast regions of the Northern Hemisphere. Why not, therefore, in Australia also? The answer is simple. The destruction was so complete that it left no Australian asylum in which a remnant might have been preserved for the future restoration of the race. The communication between Australia and Asia was also interrupted, so that re-migration from the northern continent was impossible. Besides, the climate seems to have altered in respect of average temperature. It seems now to be rather cool than warm, though exceedingly equable and favourable to the growth of ferns.

In the Upper Marine beds we observe a repetition of the submergence of land, thereby reopening the cold water channels, lowering the snow line, and stretching out the glaciers downwards even to reach the sea.

Another age of emergence and amelioration produces the Middle Coal Measures, followed in its turn by the severe interval of the Barren shales.

These oscillations, however interesting as indications of the regularity in these southern regions, as also of the alternations of climate which are so remarkably illustrated in the history of the Glacial periods of the north, are of no importance to us at this moment. But the next emergence corresponding with the Upper Coal Measures appears to deserve more particular attention. Not only have all the climatic conditions been altered by the reclosing of the cold water channels, but some kind of communication with the northern continent has been approximately completed. For, in the rivers of this period, flowing through lands covered with the very same vegetation, and in all other respects apparently just the same as the rivers of the preceding coal-forming epochs, there suddenly appears a quite new arrival from the rivers of the north. For *Urosthenes* is a Ganoid fish of the Palæoniscus family, belonging to a genus well-known in the northern Carboniferous, and makes the first appearance of a vertebrate in the Australian freshwaters.

The Ganoids are essentially freshwater fishes, and though they are tolerant of the brackish water of estuaries, and can doubtless make short voyages by sea from one river mouth to another, yet they are incapable of traversing any considerable tract of salt water, as is indeed shown by the geographical distribution of the surviving members of the order. It is a fair conclusion, therefore, that some means of communication had been at last opened between Australia and Asia. There had been, so far as can be seen, no passage of any organic form from the one land to the other since the period of the Lepidodendron flora, which must have originated in either the Northern or Southern Hemisphere, and whose existence in both requires the hypothesis of a line of communication on the Australian as well as on the American side.

It would be audacious to argue that the existence of such a bridge (or stepping-stone) between Australia and Asia indicates a greater and more extensive emergence of these regions than had occurred in the previous coal-forming periods. Yet the two things are at least not inconsistent, and the hypothesis will help to account for many otherwise inexplicable or difficult points.

Supposing then, since the supposition is allowable as such, that during this Newcastle period the western and eastern groups of islands (Australia and New Zealand) were both at the same time united (by emergence) with the Antarctic lands, and supposing also that the southern extremity of the African continent was in like manner, and at the same time, prolonged to meet a northern extension of the same, we should once again have two Oceanic regions, the sea between Australia and New Zealand on the one side, and the sea between Australia and Africa on the other, practically closed against all cold currents and continually warmed in their higher latitudes by the equatorial currents generated within the tropics. Such conditions would induce for certain the general dispersion along the maritime districts of those elements of the Australian flora and fauna which had been severally developed by one cause or another in such a way as to qualify them for a general occupation of the new territories offered by emergence and for a contest on advantageous terms with the other competitors.

Thus the *Glossopteris* flora spread into the Antarctic lands, among them east and west to New Zealand and South Africa, and perhaps also northwards from Australia across the equator towards India, then an insular tract in processs of emergence, occupied in all probability by a low and feeble flora, and open as India has ever been to the first invader.

It is unnecessary to enter into further detail. The hypothesis is sufficiently stated, but remains as it began, a hypothesis, involving the assumption that the evidence of the existence of *Glossopteris*, &c., in South Africa and New Zealand does not indicate synchronism with the *Glossopteris* series of New South Wales.

The next period in the New South Wales series (the blank in the record, which succeeds to the Newcastle Coal Measures) is again one of extreme change in the flora and on land.

It was in all probability a period of great replacement in the marine fauna also, no record of which, however, is preserved, except in the New Zealand formations; and these, though corresponding more or less, do not at present allow of a precise correlation. There is no positive evidence on this side of any submergence, though it has been strongly suspected on other grounds, and is suggested by the complete and final disappearance of the *Glossopteris* flora from New South Wales, taken together with its subsequent development elsewhere. The severity of some portion of this period is indicated by the Glacial conglomerates of Bacchus Marsh in Victoria, which can not reasonably be referred to any other epoch, and by the similar and probably contemporary characteristics of the Ecca conglomerates in South Africa. The Burrum Coal Measures of Queensland, and perhaps also the Estheria shales and even the Ballimore beds in New South Wales may possibly indicate intervals of more favourable climatic conditions, such as are testified to by unequivocal evidence during the great Glacial age of the north.

It is impossible at present to do more than guess at the (geological) length of this period, during some part of which I take the Bacchus Marsh conglomerates to have been formed. At its conclusion, however, and after these regions had settled down again under a condition of things not unlike that which had preceded, we find a different flora, quite new to this country, occupying the same ground (more or less) as the lost *Glossopteris*. This, which I call the *Tæniopteris* flora, is unanimously declared to be, from the northern standpoint, Jurassic. (If it is derived from the north it is *later*, and if from the south, *earlier* than its nominal era.) It is at any rate undoubtedly Mesozoic. The lowest and the uppermost formations of this period, taken as a whole, seem to indicate emergence or elevation of the land, so that its abundant rivers swept out in rapid descent to the ocean, bearing with them their loads of coarse detritus, and depositing only in flood-time their lighter silt and finer sand upon the surface of the plains through which they ran.

But in the middle of this period (taken as a whole) the pendulum swung back, and an intervening period of depression and refrigeration took place. Vast rivers, swift in their upper courses, and carrying with them into their lower waters enormous volumes of sand, which they, with their diminished fall, were unable any longer to carry through into the ocean, accumulated about their shifting beds the enormous masses of the Hawkesbury sandstone and its southern equivalents.

In this rock we have evidence, not as yet found in the Lower Clarence beds, of the introduction of many Ganoid fishes, of Labyrinthodonts, and of the existence of other forms whose presence seems at present inexplicable. Upon the hypothesis here adopted it would seem probable that the fish and amphibia had really made their way into this region during the preceding period of emergence (period of the Lower Clarence beds), and during the existence of a temporary "bridge" between Australia and S. E. Asia. In the same way one would account for the contemporary introduction of Labyrinthodonts in the New Zealand regions. And I have more than once shown that it is at least not improbable that *Ceratodus* and *Osteoglossum* (besides *Hatteria*) managed to effect their entrance at the same time. After the Hawkesbury interregnum, the restoration of more equable climates, owing probably to yet another emergence of the land, is testified to by the Coal Measures of the Upper Clarence beds, of Ipswich in Queensland, and of Newtown and Jerusalem in Tasmania.

If the formations of this period do really graduate upwards into the Marine Cretaceous beds of the Rolling Downs series, as suggested by Mr. Jack (above, p. 340), we have here before us a complete record of the very uneventful history of this ancient flora of Australia, from the Lower Carboniferous of both hemispheres to the Upper Jurassic of the southern, far poorer and more antique and, as it were, obsolete, than the contemporary flora of the north.

The breaks in the record are but two—one between the Lepidodendron and the Glossopteris flora, the other between the latter and the Tæniopteris.

(To be continued.)